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COST OF PUMPING THROUGH PIPE LINES[1]

By G. C. Habermeyer

Many municipalities secure water for a public supply some distance from the municipality. In a few places water flows from the source to the municipality by gravity, but in nearly all installations in this state it is necessary to pump through a pipe line. Water may be delivered directly to consumers or to a reservoir from which it is pumped or flows by gravity to consumers. The choice of a proper size for a pipe line is of considerable importance. Where reservoir capacity is not provided, pump and pipe line capacity should be sufficient to meet maximum demands. Occasionally high demand may be met in some installations by increasing pressure to correspond to increased friction losses in the pipe line, or, if water at low pressure will satisfy the extra demand, by allowing the pressure at points of consumption to drop.

In choosing a pipe line for any certain installation it is common to consider the economical velocity of flow through the pipe. This may be of considerable advantage, but it is probable that only on rare occasions will water flow at such a velocity. The loss of pressure in various sizes of pipes carrying water at a given rate of flow is often computed and the extra cost of pumping in the smaller pipes balanced against the extra first cost of the larger pipes. Officials in charge of the installation of, or changes in, a water supply would do well to consider the entire cost of pumping through the pipe line reduced to cents per thousand gallons or other unit by which water is sold. In some installations, knowing the comparatively low cost, more consideration would be given to secure a water of excellent quality at some distance, possibly from another public supply. In other instances the advantage of providing reservoir capacity to reduce fluctuations in the rate of flow or of providing good service with large-size pipe could be more readily shown.

In many cities one of the greatest difficulties in installing a public water supply is to secure active coöperation for the support of one definite project. Intelligent citizens in two small cities have been found to favor taking water from Lake Michigan more than 200 miles away. Figures on cost of pipe and pumping, estimating that with aid of other cities the water could be conveyed the first 150 miles at practically no cost, would have been rather easy to secure and would probably have convinced these people at once that another supply was preferable.

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[1] Read before the Illinois Section, March 26, 1919.

The life of a pipe line carrying water such as is in general use for public supplies is not generally affected by the velocity of flow within ordinary ranges. Therefore, to double the rate of flow divides by two the interest and depreciation charge per gallon. However, with increased rate of flow the friction increases; and, with same pipe line, the same cost of pumping 1,000,000 gallons 1 foot high, and not including interest and depreciation on the pipe line, increasing the flow 50 per cent multiplies the total cost of pumping by three.

A pipe line built without regard to increased demand in the future may result in very high pumping costs or building another line in the near future. A line built to give economical cost of pumping ten or twenty years in the future may be very expensive now on account of high interest charges on the investment. Since in many instances it is necessary to vary the rate of pumping throughout the day, the size of pipes should be so chosen that average cost will be economical. It may be economical in some cases to pump at a definite rate for several hours each day until sufficient water is pumped to meet the demand for the entire day. Interest and depreciation continue, however, when the line is not in use.

Knowing definitely the cost units, the cost may be shown best by curves, but for a basis from which to draw curves for any cost units, values are best shown by tables.

Table 1 has been prepared to show the cost of delivering water at uniform rates of flow through pipe lines. The pumping cost is taken at 10 cents per 1,000,000 gallons 1 foot high. Friction is computed by the formula of Flamant as given by diagram in "Public Water Supplies" by Turneaure and Russell. The cost of pipe is taken at $30 per ton for Class B cast-iron pipe and interest plus depreciation on the pipe line is taken at 6 per cent.

When pumping costs are low, pumping a little above the most economical rate does not greatly increase the total cost per 1,000,000 gallons. However, by choosing the pipe of next larger size the cost could, in many cases, be greatly decreased.

TABLE 1

Cost of delivering water through pipe lines by pumping at uniform rates

GALLONS A DAY	DIAMETER OF PIPE																										
	6 inches			8 inches			10 inches			12 inches			14 inches			16 inches			20 inches			24 inches			30 inches		
	Operation	Six per cent of pipe-line cost	Total	Operation	Six per cent of pipe-line cost	Total	Operation	Six per cent of pipe-line cost	Total	Operation	Six per cent of pipe-line cost	Total	Operation	Six per cent of pipe-line cost	Total	Operation	Six per cent of pipe-line cost	Total	Operation	Six per cent of pipe-line cost	Total	Operation	Six per cent of pipe-line cost	Total	Operation	Six per cent of pipe-line cost	Total
100,000	$0.42	$6.92	$7.34	$0.11	$9.12	$9.23	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
150,000	0.86	4.62	5.48	0.22	6.08	6.30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
200,000	1.43	3.47	4.90	0.36	4.56	4.92	$0.13	$6.08	$6.21	$0.05	$7.81	$7.86	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
250,000	2.11	2.77	4.88	0.53	3.64	4.17	0.18	4.84	5.02	0.08	6.25	6.33	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
300,000	2.90	2.31	5.21	0.73	3.03	3.76	0.26	4.04	4.30	0.11	5.21	5.32	$0.05	$6.22	$6.27	....	....	....	....	....	....	....	....	....	....	....	....
400,000	4.80	1.73	6.53	1.21	2.27	3.48	0.42	3.04	3.46	0.18	3.90	4.08	0.09	4.66	4.75	....	....	....	....	....	....	....	....	....	....	....	....
500,000	7.10	1.39	8.49	1.78	1.82	3.60	0.62	2.42	2.84	0.27	3.12	3.39	0.13	3.72	3.85	$0.07	$4.50	$4.57	....	....	....	....	....	....	....	....	....
600,000	9.77	1.15	10.92	2.46	1.52	3.98	0.86	2.02	2.88	0.36	2.60	2.96	0.18	3.11	3.29	0.09	3.75	3.84	....	....	....	....	....	....	....	....	....
800,000	16.15	0.86	17.01	4.06	1.13	5.19	1.42	1.52	2.94	0.60	1.95	2.55	0.29	2.33	2.62	0.15	2.81	2.96	$0.05	$3.90	$3.95	....	....	....	....	....	....
1,000,000	....	....	....	6.00	0.91	6.91	2.10	1.21	3.31	0.89	1.56	2.45	0.43	1.87	2.30	0.23	2.25	2.48	0.08	3.12	3.20	....	....	....	....	....	....
1,200,000	....	....	....	8.26	0.76	9.02	2.89	1.01	3.90	1.23	1.30	2.53	0.59	1.55	2.14	0.31	1.88	2.19	0.11	2.60	2.71	$0.04	3.39	$3.43	....	....	....
1,400,000	....	....	....	....	....	....	3.78	0.87	4.65	1.61	1.11	2.72	0.78	1.33	2.11	0.41	1.61	2.02	0.14	2.23	2.37	0.05	2.90	2.96	....	....	....
1,600,000	....	....	....	....	....	....	4.77	0.76	5.53	2.04	0.97	3.01	0.98	1.16	2.14	0.52	1.40	1.92	0.18	1.95	2.13	0.08	2.54	2.62	....	....	....
2,000,000	....	....	....	....	....	....	....	....	....	3.01	0.78	3.79	1.45	0.94	2.39	0.76	1.13	1.89	0.25	1.56	1.81	0.11	2.04	2.15	$0.04	$2.93	$2.97
2,400,000	....	....	....	....	....	....	....	....	....	4.13	0.65	4.78	1.99	0.77	2.76	1.05	0.94	1.99	0.36	1.30	1.66	0.15	1.70	1.85	0.05	2.44	2.49
2,800,000	....	....	....	....	....	....	....	....	....	....	....	....	2.60	0.66	3.26	1.37	0.80	2.17	0.48	1.11	1.59	0.20	1.45	1.65	0.07	2.09	2.16
3,200,000	....	....	....	....	....	....	....	....	....	....	....	....	3.29	0.58	3.87	1.74	0.70	2.44	0.60	0.98	1.58	0.25	1.27	1.52	0.09	1.83	1.92
3,600,000	....	....	....	....	....	....	....	....	....	....	....	....	4.03	0.52	4.55	2.13	0.63	2.76	0.74	0.87	1.61	0.31	1.13	1.44	0.11	1.63	1.74
4,000,000	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.56	0.56	3.12	0.89	0.78	1.67	0.37	1.02	1.39	0.13	1.46	1.59
5,000,000	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.80	0.45	4.25	1.32	0.62	1.94	0.55	0.82	1.37	0.19	1.17	1.36
6,000,000	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.81	0.52	2.33	0.76	0.68	1.44	0.26	0.98	1.24
8,000,000	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.00	0.39	3.39	1.25	0.51	1.76	0.43	0.73	1.16
10,000,000	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.86	0.41	2.27	0.63	0.58	1.21
12,000,000	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.56	0.34	2.90	0.87	0.49	1.36
14,000,000	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.15	0.42	1.56
16,000,000	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.45	0.37	1.82

Costs for pumping part time at uniform rate may be computed from the table. For example, pumping through a 10-inch pipe line at a rate of 1,000,000 gallons a day, an average of eight hours a day, the cost of the pipe line per 1,000,000 gallons would be three times that given in the table or $3.63. Operation, if cost is 10 cents per 1,000,000 gallons 1 foot high, would be $2.10 as given; total, $5.63. Pumping for eight hours at a rate of 500,000 gallons a day and for sixteen hours at a rate of 1,000,000 gallons a day, the cost would be one-sixth of a million at $2.84 = $0.47, plus two-thirds of a million at $3.31 = $2.20; a total of 833,000 gallons at a cost of $2.67 or $3.20 per 1,000,000 gallons. For various costs of pumping corrections may readily be made. For cost of pipe delivered to the station within 1 or 2 miles of construction work other than $30 per ton, the cost may be closely approximated by varying the cost on the pipe line and the 6 per cent on investment proportionately, as the cost of iron is a large part of the cost and generally when pipe is high labor is also high. The actual cost of the pipe-line chosen for the table may readily be found, as 6 per cent of the cost is given.

DISCUSSION

M. L. Enger: In considering only interest, depreciation and cost of operation, as these terms are usually understood, the author has omitted an important factor, the uncertainty of the future. This factor may be taken account of by an increase in the allowance for interest and depreciation as insurance against loss of principal and dividends. The amount of the insurance would depend upon the circumstances. Water companies will not make the extra investment required to put in a large pipe when it is shown by calculation, as given in the article, that a smaller pipe is as economical, unless satisfactory allowances have been made for possible future loss on the larger investment.

P. E. Green: That problem was one that had to be solved in the work of the U. S. Housing Corporation, particularly where the government had to deal with private water companies. Possibly there would be some 2 or 3 miles of large main to connect to the housing development. The corporation had G. T. Prince, formerly chief engineer of the Omaha and Denver water works, with it and he took up that problem. He reached the general conclusion that the most economical size of pipe was one in which the velocity was over 4 feet per second. It seemed to work out very well.

L. R. Howson: Probably Mr. Prince's computation took into account that the work was temporary and that he could spend more on operation than he could in a plant which would be in service a long period of years. That was tried in a large number of cantonment jobs and it is the speaker's recollection that the figures showed for plants for permanent installation the economical velocity was nearer 3 than 5.

P. E. Green: In Mr. Prince's computations everything was intended for permanent construction. His figures were based on present prices but not on top prices. The best price was $50 to $55 for pipe. That is about twice what was paid in previous times, but although the high expense would tend to increase the most economical velocity, still all prices moved in parallel lines.

W. W. Deberard: It is possible that the coal price might go down but the investment in iron would not go down. The old figure of 3 feet per second is what was formerly used.

G. C. Habermeyer: The economical velocity will probably vary a little with the size of the pipe. Only interest, depreciation and costs of pumping were considered in the paper, and it is well to keep in mind, as Mr. Enger suggests, that in an actual installation other factors must be considered.